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Newfoundland and Labrador and Region

Canadian Science Advisory Secretariat
Science Advisory Report 2015/018

ASSESSMENT OF NORTHERN SHRIMP (*Pandalus borealis*) IN SHRIMP FISHING AREAS 4-6 (NAFO DIVISIONS 2G-3K) AND OF STRIPED SHRIMP (*Pandalus montagui*) IN SHRIMP FISHING AREA 4 (NAFO DIVISION 2G)

Top: Northern Shrimp (Pandalus borealis)
Bottom: Striped Shrimp (Pandalus montagui)
Photo: Fisheries and Oceans Canada, Newfoundland and Labrador Region.

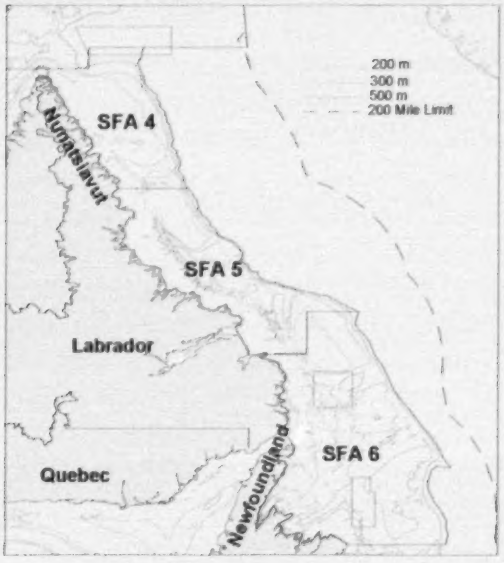

Figure 1. Map of shrimp fishing areas (SFAs) 4 - 6. Blue boxes indicate closed areas (Coral box, Hawke box and Funk Island Deep box from North to South).

Context:

*The bottom trawl fishery for Northern Shrimp (*Pandalus borealis*) off the coast of Labrador began in the mid-1970s, primarily in the Hopedale and Cartwright channels (Shrimp Fishing Area (SFA) 5), expanding north to SFA 4 and south to SFA 6 through the 1980s. Striped Shrimp (*Pandalus montagui, *Leach, 1814) in SFA 4 are primarily taken as by-catch during the Northern Shrimp fishery in that area.*

Fisheries and Oceans Canada (DFO) Ecosystems and Fisheries Management requested science advice on the status of Northern Shrimp in SFAs 4, 5 and 6 and on the status of Striped Shrimp in SFA 4. SFAs 4-6 Northern Shrimp were last assessed during February 2013 (DFO 2013) and updated in 2014 (DFO 2014b). Striped Shrimp were last assessed in January 2014 (DFO 2014a). Beginning in 2015, both will be assessed on a biennial basis, with updates in the interim years.

The assessment made use of fishery data from observer and logbook datasets, from the Canadian Atlantic Quota Report (CAQR) and data from fall and summer bottom trawl surveys. Together these provided information on catch rates, distribution, exploitation rate and biomass.

This Science Advisory Report is from the February 17-23, 2015 Assessment of Northern and Striped Shrimp. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

May 2015

Canada

SUMMARY

- Resource status of Northern Shrimp in Shrimp Fishing Areas (SFAs) 5 and 6 was updated based on DFO fall multi-species trawl survey data (1996-2014). Resource status for Northern Shrimp and Striped Shrimp in SFA 4 was updated based on Northern Shrimp Research Foundation (NSRF)-DFO summer trawl survey data (2005-14).
- Trawl survey data for SFAs 4-6 provided information on shrimp distribution, length frequencies, and biomass. Trends in fisheries performance were inferred from total allowable catch (TAC), commercial catch to date, fishery catch per unit effort (CPUE) and fishing patterns.

Environment and Ecosystem

- Data from SFAs 5 and 6 indicate that shrimp constitutes an important part of the diet of many groundfish species. In recent years the fraction of shrimp in the diets has declined, while another key forage species, Capelin, has been increasing. Relevant data from SFA 4 are lacking.
- In SFA 6, total biomass of fishes that are potential shrimp predators has increased. As a consequence, their consumption of all types of food was estimated to have tripled since the late 1990s, and has remained around that level since 2010. Estimates of total predation on shrimp peaked in 2011 and have since declined to be around twice the level of the mid-2000s. Future trends will depend on the trajectory of predator biomass and availability of alternative prey, like Capelin.

SFA 6 *Pandalus borealis*

- Commercial catch has been about 60,000 t over the past four years. It is expected that the 2014/15 TAC of 48,196 t will be taken.
- Large vessel standardized CPUE has varied without trend since 2010 while small vessel CPUE has been increasing.
- Fishable biomass index declined from 421,000 t in 2011 to 216,000 t in 2013, the lowest in the time series, and increased slightly to 233,000 t in 2014.
- Female spawning stock biomass (SSB) index declined from 250,000 t in 2011 to about 136,000 t in 2013 and 2014, the lowest level in the series.
- Climate-driven changes (e.g., time of phytoplankton bloom) and increases in predation pressure suggest low recruitment to the fishable biomass in the medium term.
- The exploitation rate index ranged between 5.6% and 22.3% from 1997 to 2014/15, and has averaged 18.3% in the last five years. The 2014/15 exploitation rate index will be 22.3% if the TAC is taken.
- Female SSB index, at its lowest level in the time series, was assessed to be below the midpoint of the cautious zone within the Integrated Fisheries Management Plan (IFMP) Precautionary Approach (PA) Framework. If the 48,196 t TAC is maintained and taken in the 2015/16 season, the exploitation rate index will be 20.7%.

SFA 5 *Pandalus borealis*

- Commercial catch had been about 23,000 t over the past five years. It is expected that the 2014/15 TAC of 20,970 t will be taken.
- Standardized large vessel CPUE increased over the last 4 years.

- Fishable biomass index has been relatively stable since 2010, and was 116,000 t in 2014.
- Female SSB index has changed little since 2010, and was 60,000 t in 2014.
- Climate-driven changes (e.g., time of phytoplankton bloom) and increases in predation suggest low recruitment to the fishable biomass in the medium term.
- The exploitation rate index has varied without trend and averaged 18% since 2010.
- Female SSB index was assessed to be in the Healthy Zone within the IFMP PA Framework. If the 20,970 t TAC is maintained and taken in 2015/16, then the exploitation rate index will be 18.1%.

SFA 4 *Pandalus borealis*

- Commercial catch increased from approximately 10,000 t from 2005/06 – 2011/12 to about 15,000 t in the past two years.
- Since 2010, large vessel standardized CPUE fluctuated above the long term mean.
- Fishable biomass index has been relatively stable since 2010, and was 134,000 t in 2014.
- Female SSB index has changed little since 2010 and was 89,800 t in 2014.
- Prospects for recruitment to the fishable biomass are uncertain.
- Since 2010, the exploitation rate index has shown an increasing trend, and reached 11.2% by 2014/15.
- Female SSB index was assessed to be in the Healthy Zone, within the IFMP PA Framework.

SFA 4 *Pandalus montagui*

- Commercial catch of *P. montagui*, taken as by-catch in the *P. borealis* fishery, increased from 280 t in 2008 to 4,700 t in 2012 and declined to 1,200 t in 2014. The by-catch limit of 4,033 t has not been taken in the past two years.
- Fishable biomass index has doubled since 2010 and was 34,100 t in 2014.
- Female SSB is unknown.
- Prospects for recruitment to the fishable biomass are unknown.
- The exploitation rate index would have been 11.8% in 2014/15 if the by-catch limit had been taken.

BACKGROUND

Species Distribution and Stock Boundaries

Northern or Pink Shrimp (*Pandalus borealis*) are found in the Northwest Atlantic from Baffin Bay south to the Gulf of Maine. Striped shrimp (*Pandalus montagui*) are found in the Northwest Atlantic from Davis Strait south to the Bay of Fundy. Northern Shrimp prefer an ocean floor that is somewhat soft and muddy and where temperatures range from about 1°C-6°C. These conditions typically occur at depths of 150-600 m and exist throughout the Newfoundland and Labrador offshore area. In contrast, Striped Shrimp prefer a hard bottom and are typically found in colder waters from 1°C-2°C at depths of 100-300 m. Although the temperature, depth and bottom type preferences differ slightly between species, their populations overlap; the extent of the overlap has not been examined. Northern Shrimp represents the primary cold-water shrimp resource in the North Atlantic.

Both species are found over a wide area in SFA 4. While management boundaries are, to some extent, arbitrary and chosen for convenience, the northern edge of SFA 4 is an especially inconvenient place for a boundary; applying a similar harvest strategy across all areas mitigates the consequence of potential boundary issues. In addition to being found in SFA 4, both *P. borealis* and *P. montagui* are found in the Eastern and Western Assessment Zones, directly to the north of SFA 4. Hudson Strait is a highly dynamic system with strong currents and mixing. Shrimp could be transported a great distance in a relatively short period of time, resulting in rapid shifts of shrimp into and out of SFA 4.

Further to the issues of transport across the northern boundary of SFA 4, the Labrador Current runs southward from SFA 4, through SFAs 5 and 6. This current transports shrimp, particularly larvae, from north to south; however the extent and effects are unknown.

Species Biology

Both Northern and Striped Shrimp are protandrous hermaphrodites. They are born and first mature as males, mate as males for one or more years and then change sex to spend the rest of their lives as mature females. They are thought to live for more than eight years in some areas, though techniques used for determining shrimp ages have been imprecise. Some northern populations exhibit slower rates of growth and maturation, but greater longevity results in larger maximum size. Females produce eggs in the late summer-fall and carry the eggs on their pleopods until they hatch in the spring.

Shrimp are thought to begin to recruit to the fishery around age three. Most of the fishable biomass is female.

During the daytime, shrimp rest and feed on or near the ocean floor. At night, substantial numbers migrate vertically into the water column, feeding on zooplankton. They are important prey for many species such as Atlantic Cod (*Gadus morhua*), Greenland Halibut (*Reinhardtius hippoglossoides*), redfish (*Sebastes sp.*), skates (*Raja radiata, R. spinicauda*), wolffish (*Anarhichas sp.*), Snow Crab (*Chionoecetes opilio*) and Harp Seal (*Phoca groenlandica*).

Fishery

The fishery for Northern Shrimp off the coast of Labrador began in SFA 5 (Figure 1) in the mid-1970s, primarily in the Hopedale and Cartwright Channels. Soon after, concentrations of Northern Shrimp were located within SFAs 4 and 6 leading to an expansion of the fishery into those areas. As the fishery expanded to the St. Anthony Basin, Funk Island Deep and the slope of the continental shelf in SFAs 4-6 during the early 1990s, TACs were increased periodically and were taken in most years (Figure 2).

Commercial catch of Northern Shrimp increased rapidly from the mid-1990s into the early 2000s within SFA 6, where the resource was considered to be healthy and exploitation low. The majority of TAC increases in this period were reserved for the development of a small vessel (< 100 feet) fleet, which has since grown to include about 250 license holders.

In 2003 the management year was changed from a calendar (January 1-December 31) to a fiscal (April 1-March 31) year. To facilitate this change, an additional interim 20,229 t quota was allocated to the large vessel fleet during the 15 month long management year (January 1, 2003 to March 31, 2004). In 2007, a seasonal bridging program was established that allows each license holder to carry over 750 t of unused quota from the previous year, or borrow from the next year's quota.

Due to declining resource status in SFA 6 in 2009 and 2010, the SFA 6 TAC was decreased in accordance with the PA Framework (DFO 2006; DFO 2007a), reducing the overall TACs to 96,252 t in 2010/11 and 87,007 t in 2011/12. In 2011, resource status improved in SFA 6 and remained positive in SFA 4. TACs were increased in both areas, while the TAC in SFA 5 remained the same, leading to an

overall TAC of 96,563 t. In 2013/14 the TAC was again increased in SFA 4 leading to an overall TAC of 98,516 t.

Due to significant declines in resource status for SFAs 5-6 in 2013, TACs for 2014/15 were reduced by 10% in SFA 5 and 20% in SFA 6 but stayed the same in SFA 4. The overall TAC was 84,137 t. Instances (overall or by SFA) where the TAC was not taken are often due to operational or market constraints and not the inability to catch shrimp.

Northern Shrimp has generally been the target shrimp species in SFA 4. Management measures implemented in 2013/14 designate SFA 4 Striped Shrimp as a by-catch only fishery with a harvest limit of 4,033 t. Northern Shrimp are usually more valuable and marketable than Striped Shrimp. Depending on market conditions, and in order to reduce by-catch, vessels often move away from areas where the catch has a significant portion of Striped Shrimp.

While the fishery is open year-round in SFAs 4-6, ice conditions in SFA 4 typically only allow access from early summer to late fall or early winter. Moreover, the catch of Striped Shrimp is mainly at the northern fringe of SFA 4 (north of 60°N), rather than being distributed over the entire SFA.

All Northern Shrimp fisheries in eastern Canada are subject to the Atlantic Fisheries Regulations regarding territorial waters, by-catch, discards, vessel logs, etc. These include a minimum mesh size of 40 mm and mandatory use of sorting grates to minimize by-catch of non-target species. Grate size is dependent upon area fished. In SFA 6 the minimum bar spacing is 22 mm and in SFAs 4-5 the minimum bar spacing is 28 mm. Observers are required on all trips by the large vessel fleet. A target of 10% observer coverage has been established for the small vessel fleet, although rarely achieved.

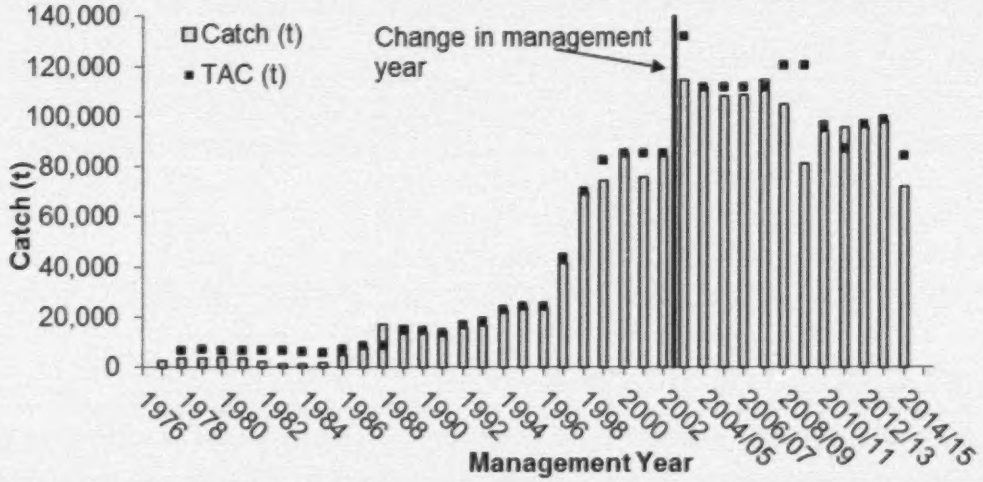

Figure 2. Historical Northern Shrimp catches (SFAs 4-6) and TACs for the period 1977-2014/15. 2014/15 catches are preliminary and from the Canadian Atlantic Quota Report of January 30, 2015. The black vertical line indicates the year in which the fishery switched from a calendar to a fiscal year.

ASSESSMENT

The key considerations for assessment of a renewable resource are how fast the resource is renewing itself, how this might change, and how human activity can affect it. In management terms, the first consideration would translate as the harvest that is sustainable. For ecosystem-based management, 'harvest' would be replaced by some combination of harvest and ecosystem function.

This assessment follows the framework developed in 2007 for Northern Shrimp off Labrador and the northeastern coast of Newfoundland (DFO 2007a). Resource status of Northern Shrimp in SFAs 5 and

6 was updated based on DFO fall multi-species trawl survey data (1996-2014). Resource status for Northern Shrimp and Striped Shrimp in SFA 4 was updated based on NSRF-DFO summer trawl survey data (2005-14).

Trawl survey data for SFAs 4-6 provided information on shrimp distribution, length frequencies, and biomass. Fishable biomass is defined as the weight of all males and females with a carapace length > 17 mm and female SSB is defined as the weight of all female shrimp. It is not possible to infer recruitment from observations of pre-recruits. No correlation between pre-recruit numbers and subsequent changes in fishable biomass has been observed. Trends in fisheries performance were inferred from TACs, commercial catch to date, fishery CPUE and fishing patterns.

Exploitation rate index was determined by dividing the commercial catch by the survey fishable biomass from the previous year (for fall surveys) or the current year (for summer surveys).

Biomass indices are derived from ogive mapping methods (Ogmap). A new version of Ogmap was developed in 2014/15 which incorporates refinements in how to interpolate between survey observations. For this reason, indices of biomass are slightly different than those of previous assessments.

There is an IFMP for shrimp in SFAs 4-6 (DFO 2007b). Reference points for the DFO PA framework (DFO 2006) were developed using proxies (DFO 2009). The upper stock reference (USR) was defined as 80%, and limit reference point (LRP) as 30%, of the geometric mean of female SSB index over a productive period. Because of differences in survey history, the reference periods were taken to be 1996-2003 for SFA 6, 1996-2001 for SFA 5 and 2005-09 for SFA 4.

SFA 6 *Pandalus borealis*

Environment and Ecosystem Considerations

The marine fish community collapsed in the late 1980s and early 1990s. After the collapse it became dominated by shellfish, mainly shrimp, which reached its highest biomass in the mid-2000s. Since then, overall biomass of the fish community has been increasing and changing back towards a finfish dominated structure. Despite the overall increase in biomass, current levels of finfish are still well below pre-collapse levels.

Data from Northwest Atlantic Fisheries Organization (NAFO) divisions 2J3KL (SFAs 7, 6 and southern SFA 5) indicate that shrimp constitutes an important part of the diet of many groundfish species. In recent years the fraction of shrimp in the diets has declined, while another key forage species, Capelin, has been increasing (Figure 3). Relevant data from SFA 4 are lacking.

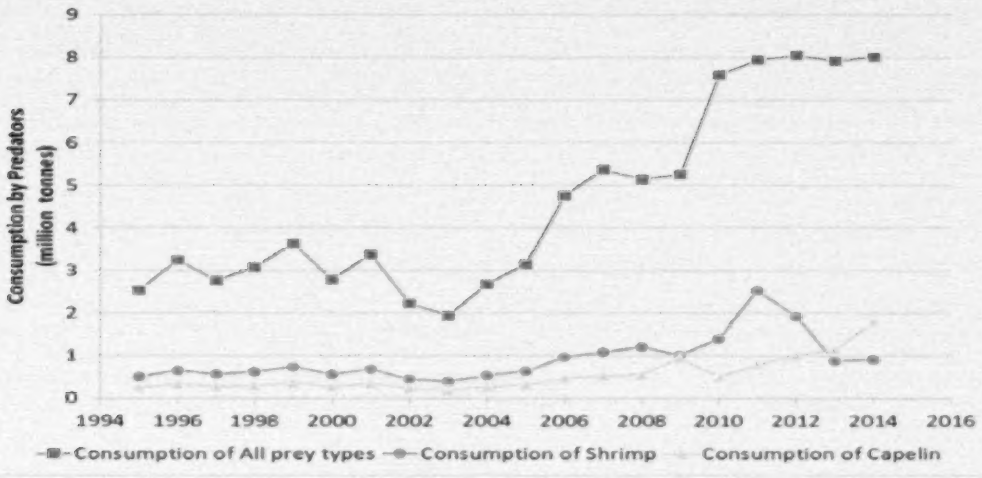

Figure 3. Median of estimates of consumption of all prey types (green squares), shrimp (red circles), and capelin (orange triangles) by those fish functional groups considered predators of shrimp and capelin (medium and large benthivores, piscivores, and plank-piscivores). The fractions of shrimp and capelin were derived from stomach content analysis of key groundfish species.

In SFA 6, total biomass of fishes that are potential shrimp predators has increased. As a consequence their consumption of all types of food was estimated to have tripled since the late 1990s, and has remained around that level since 2010 (Figure 3). Estimates of total predation on shrimp peaked in 2011 and have since declined to be around twice the level of the mid-2000s. Future trends will depend on the trajectory of predator biomass and availability of alternative prey, like capelin.

It is a general principle that prey and predator levels cannot be maintained at their highest levels of biomass simultaneously. Thus shrimp biomass may not be maintained at a high level during a groundfish dominated period. Moreover, current trends in environmental conditions (e.g., changes in timing of phytoplankton bloom, general warming) are not favourable for shrimp production.

Fishery

The TAC was set at 11,050 t in 1994 and increased to 23,125 t in 1997 (Figure 4) as a first step towards increasing the exploitation of an abundant resource. Most of the increase was reserved for development of the small vessel fleet. The TAC more than doubled between 1997 and 1999, increased to 61,632 t in 2002 and then to 77,932 t in 2003. An additional interim quota of 7,653 t was set for the fishing season January 1, 2003-March 31, 2004. Thus the 2003/04 management period was fifteen months long and had an 85,585 t TAC. As a result of the seasonal bridging program, the 77,932 t TAC for 2007/08 was increased by 2,000 t. The TAC was increased to 85,725 t in 2008/09 and maintained through 2009/10. The 2010/11 TAC was reduced to 61,632 t and further to 52,387 t in 2011/12. Resource status improved during 2011 and subsequently the TAC for 2012/13 was increased to 60,245 t and maintained through 2013/14. The TAC was reduced in 2014/15 to 48,196 t and will likely be taken. Commercial catch has been about 60,000 t over the past four years.

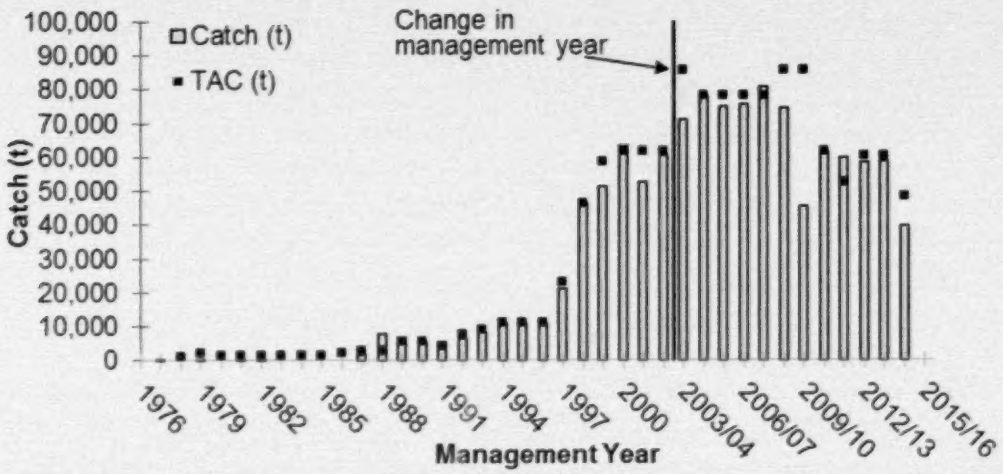

Figure 4. Historical Northern Shrimp catch and TAC in SFA 6 for the period 1977-2014/15. 2014/15 values are preliminary and based upon the Canadian Atlantic Quota Report (CAQR) as of January 30, 2015. In 2003, the management year changed from a calendar to a fiscal year.

Large vessel standardized CPUE has varied without trend since 2010 while small vessel CPUE has been increasing (Figure 5).

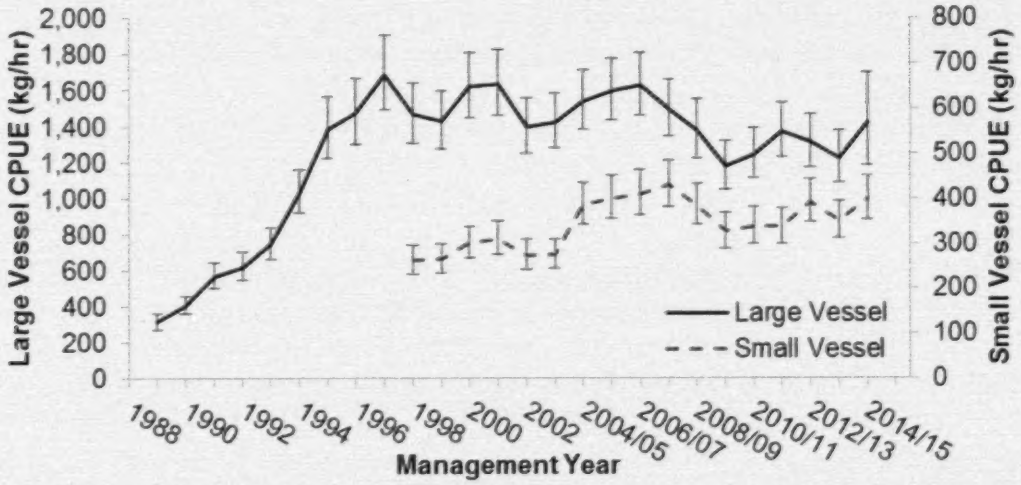

Figure 5. SFA 6 large vessel standardized CPUE (solid line) and small vessel standardized CPUE (dashed line). Error bars indicate 95% confidence intervals.

Biomass

Fishable biomass index declined from 421,000 t in 2011 to 216,000 t in 2013, the lowest in the time series, and increased slightly to 233,000 t in 2014. Female SSB index declined from 250,000 t in 2011 to about 136,000 t in 2013 and 2014, the lowest level in the series (Figure 6).

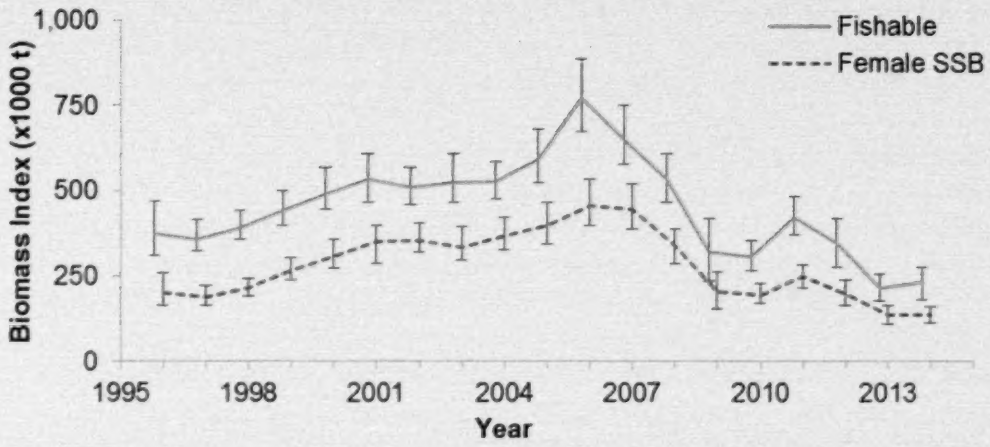

Figure 6. SFA 6 fishable (green solid line) and female spawning stock (purple dashed line) biomass indices. Error bars indicate 95% confidence intervals.

Renewal

Resource renewal was examined considering both the causes of net change in population as a result of production (growth and reproduction) and predation (including fishing), and inferences that could be drawn from time series of shrimp data.

Renewal is the difference between the increase due to production, and removal largely due to predators. The amount of biomass produced by a unit of biomass of a given species during a year is commonly known as the production over biomass ratio (P/B) (Allen 1971); although actual P/B ratios are expected to vary, and expectation of annual production can be estimated under certain assumptions (e.g. average conditions) (Allen 1971; Mertz and Myers 1998). The P/B ratio for shrimp has been estimated to be around 1.7 (Robertson 1979; and Hopkins1988), which implies that the biomass of shrimp available for consumption should be somewhere between 1 and 2.7times the initial biomass. For NAFO Divisions 2J3KL (largely corresponding to SFA 6), estimates of predation by fish were obtained based on the mass of shrimp found in predator stomachs during the autumn multi-species survey (Figure 7).

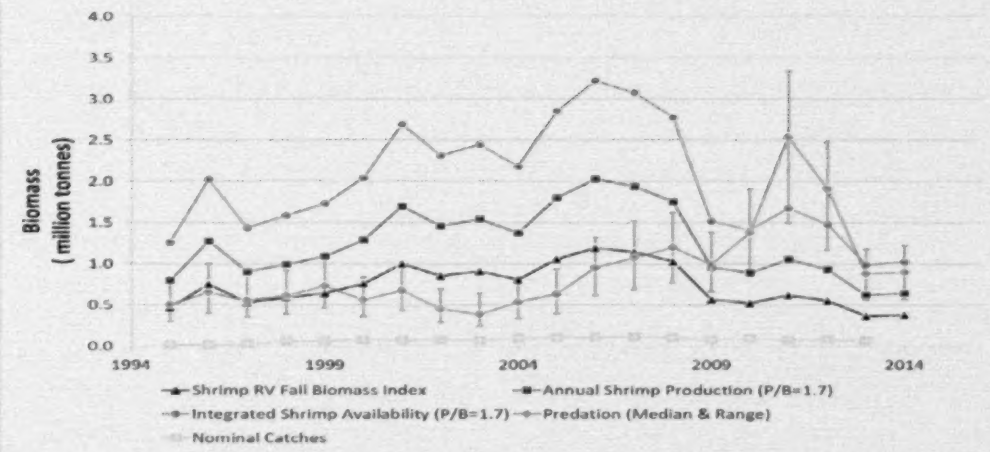

Figure 7. Comparison of predation and fisheries catches with the Integrated Shrimp Availability derived from the DFO Fall survey Biomass Index for shrimp, and a P/B ratio of 1.7.

Uncertainty about various conversion factors (e.g., P/B ratio, species catchability, conversion from gut contents to predation rates) makes it difficult to derive precise conclusions, especially when subtracting two series that depend on different factors; but production appears to have sufficiently exceeded predation until about 2010. The population of natural predators suggests low recruitment to the fishable biomass in recent years. Climate-driven changes (e.g., time of phytoplankton bloom) also suggest low recruitment to the fishable biomass in the medium term. Early blooms associated with warming appear to be related to high larval mortality.

Fishery removals appear to be a small fraction of total removals by all predators. Even so, they may be a large fraction of the net difference between shrimp production and total predation in recent years. Thus, fishing mortality may be very important for determining whether gains (production) exceed losses (predation) and hence whether the stock is increasing or decreasing.

Exploitation

The 2014/15 exploitation rate index will be 22.3% if the TAC is fully taken (Figure 8). The exploitation rate index ranged between 5.6% and 22.3% from 1997 to 2014/15, and has averaged 18.3% in the last five years.

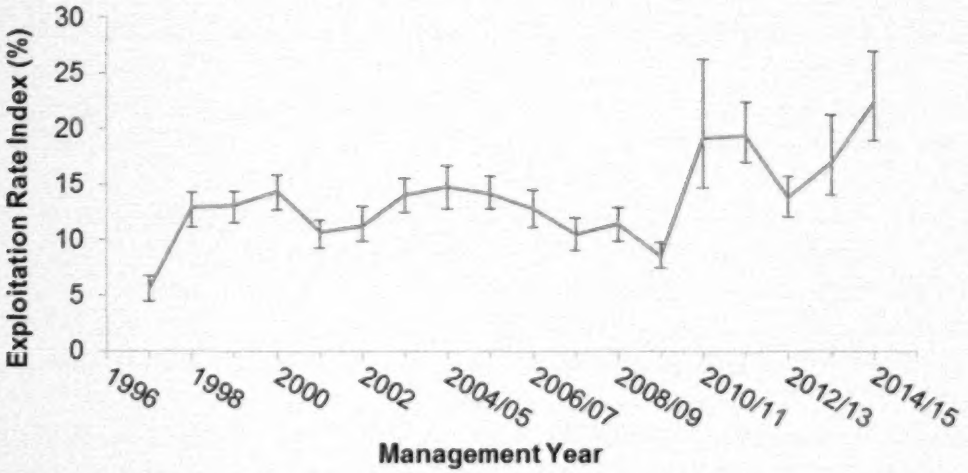

Figure 8. SFA 6 exploitation rate index, based on total catch in current year/fishable biomass index from previous year, expressed as a percentage. The 2014/15 point assumes that the 48,196 t TAC will be taken. Error bars indicate 95% confidence intervals.

Current Outlook and Prospects

Female SSB index, at its lowest level in the time series in 2014, and was assessed to be below the midpoint of the cautious zone within the PA framework. If the 48,196 t TAC is maintained and taken in the 2015/16 season, the exploitation rate index will be 20.7% (Figure 9).

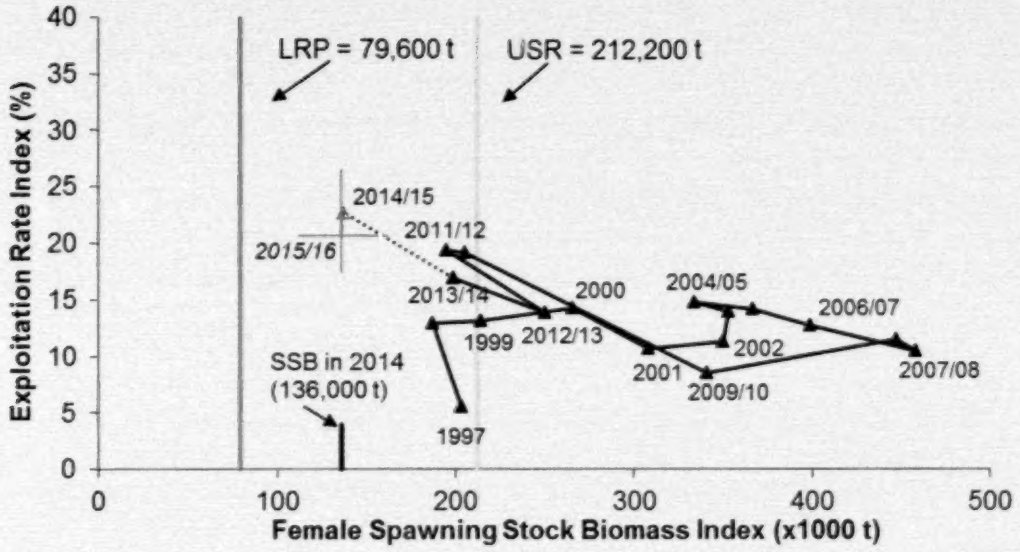

Figure 9. SFA 6 IFMP PA framework with trajectory of exploitation rate index versus female spawning stock biomass index. Point labels denote year of the fishery. The 2014/15 fishery was ongoing, however it is expected that the TAC will be taken, and hence the 2014/15 point is based upon the TAC rather than catch to date. The red cross on the 2015/16 point indicates 95% confidence intervals for the 2014 female SSB index (horizontal) and the 2015/16 exploitation rate index (vertical), assuming that the 48,196 t TAC is maintained and taken in the 2015/16 fishery.

SFA 5 *Pandalus borealis*

Fishery

The TAC doubled from 7,650 t in 1994-96 to 15,300 t over the 1997-2002 period. In 2003, the TAC increased to 23,300 t, the management year changed from January 1-December 31 to April 1-March 31, and an additional interim quota of 9,787 t was set for the fifteen month 2003/04 management year; hence 2003/04 had a 33,087 t TAC. The TAC of 23,300 t was maintained through to 2013/14. In 2013 the resource status appeared to decline and the TAC was set at 20,970 t for 2014/15. Commercial catch had been about 23,000 t over the past five years and it is expected that the 2014/15 TAC of 20,970 t will be taken (Figure 10).

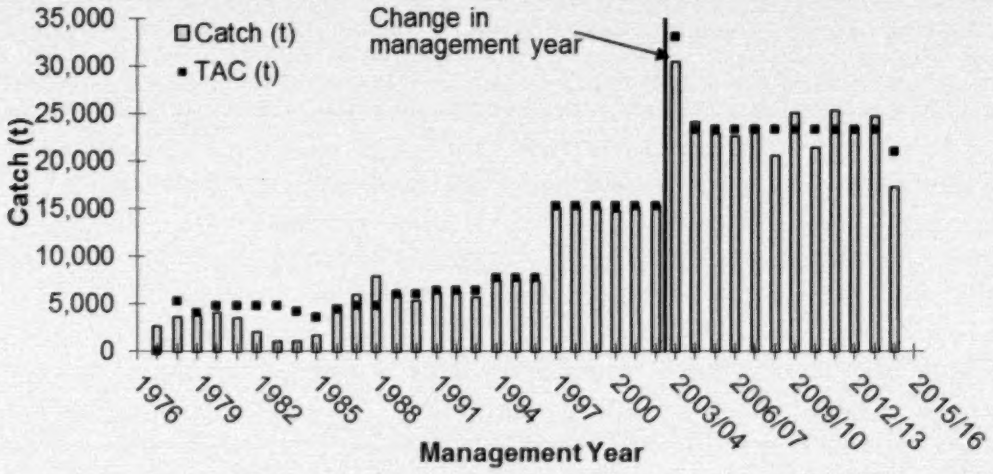

Figure 10. Historical Northern Shrimp catches and TAC, in SFA 5, for the period 1977-2014/15. 2014/15 values are preliminary and based upon the CAQR as of January 30, 2015. In 2003, the management year changed from a calendar to a fiscal year.

Standardized large vessel CPUE increased over the last 4 years (Figure 11).

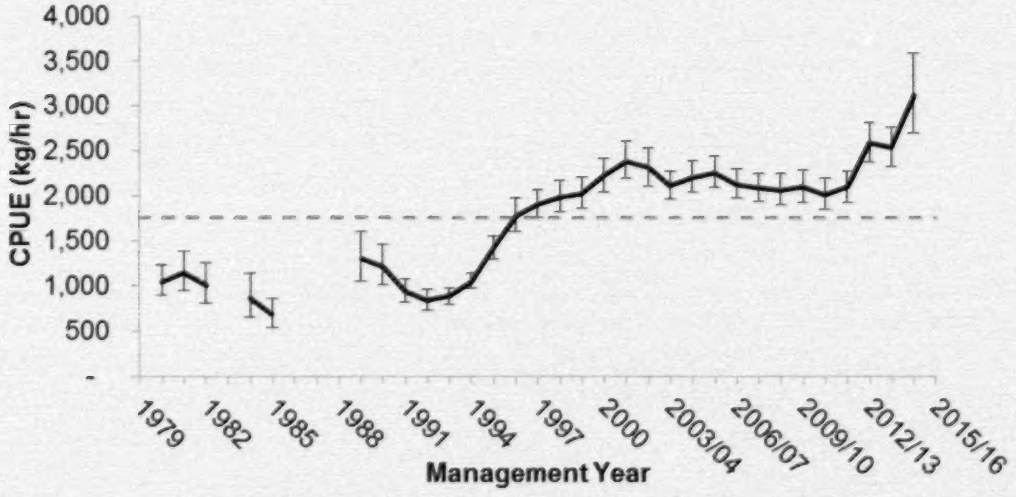

Figure 11. SFA 5 large vessel standardized CPUE. Error bars indicate 95% confidence intervals and the dashed line indicates the long term average.

Biomass

Fishable biomass index has been relatively stable since 2010, and was 116,000 t in 2014. Female SSB index has changed little since 2010, and was 60,000 t in 2014 (Figure 12). The low 2013 biomass indices were likely due to a survey year-effect.

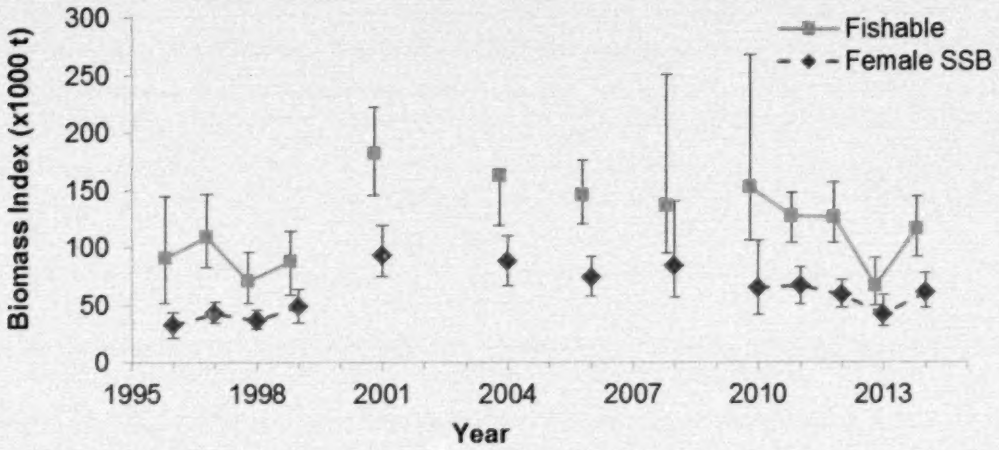

Figure 12. SFA 5 fishable (green solid line) and female spawning stock (purple dashed line) biomass indices. Error bars indicate 95% confidence intervals.

Recruitment

As in SFA 6, climate-driven changes (e.g., time of phytoplankton bloom) and increases in predation pressure suggest low recruitment to the fishable biomass in the medium term.

Exploitation

The exploitation rate index has varied without trend and averaged 18% since 2010 (Figure 13). If the low 2013 fishable biomass index was due to a survey year-effect, then the high exploitation rate index for 2014/15 is spurious.

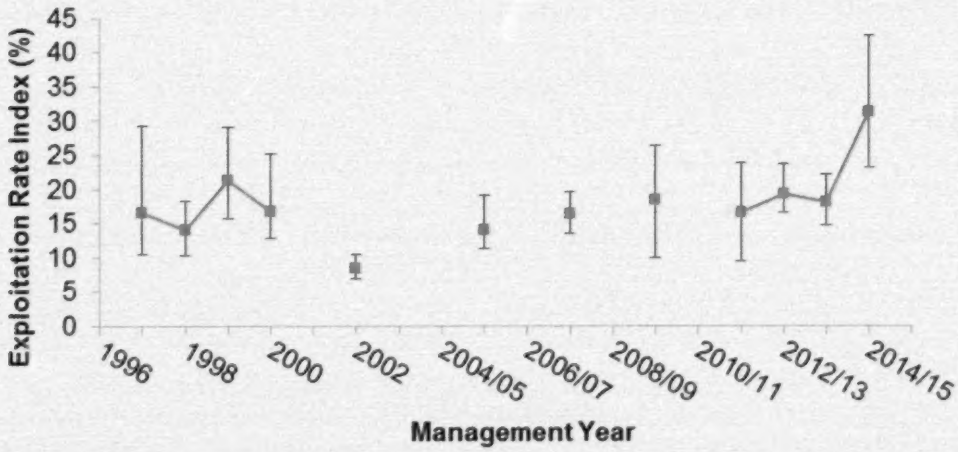

Figure 13. SFA 5 exploitation rate index, based on total catch in current year/fishable biomass index from previous year, expressed as a percentage. The exploitation rate index in 2014/15 assumes the 20,970 t TAC will be taken. Error bars indicate 95% confidence intervals.

Current Outlook and Prospects

Female SSB index was assessed to be in the Healthy Zone within the PA Framework. If the 20,970 t TAC is maintained and taken in 2015/16, then the exploitation rate index will be 18.1% (Figure 14).

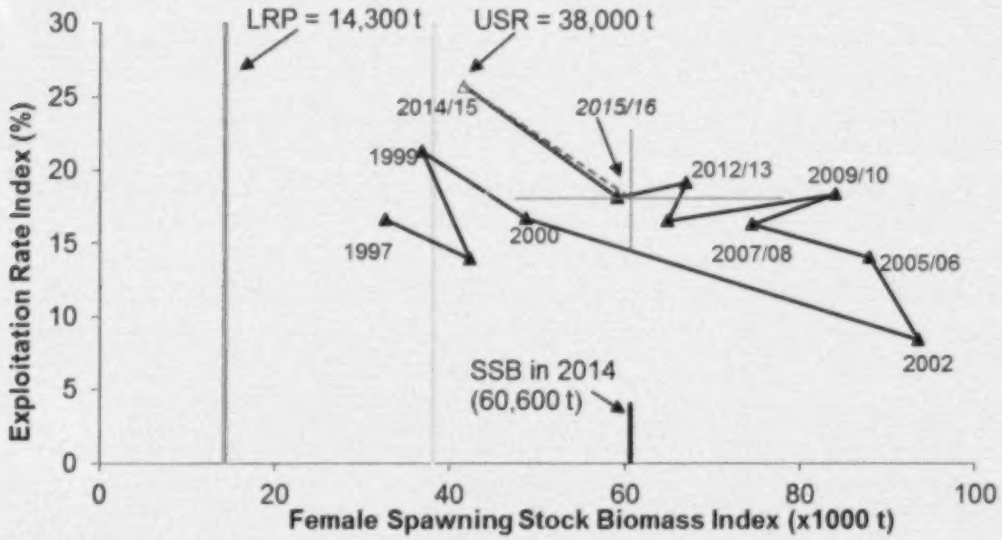

Figure 14. SFA 5 IFMP PA framework with trajectory of exploitation rate index versus female spawning stock biomass index. Point labels denote year of the fishery. The 2014/15 fishery was ongoing and the 2014/15 point is based on reported catch as of January 30, 2015.The red cross on the 2015/16 point indicates 95% confidence intervals for the 2014 female SSB index (horizontal) and the 2014/15 exploitation rate index (vertical), assuming that the 20,970 t TAC is maintained and taken in the 2015/16 fishery.

SFA 4 *Pandalus borealis*

Fishery

The TAC increased from 2,580 t in 1989 to 5,200 t in 1995 and 9,320 t in 1998. In 1998, 2,184 t of the TAC was allocated to the area south of 60°N to promote spatial expansion of the fishery. The 2003 TAC was increased to 10,320 t. In 2003 the management year changed from January 1-December 31 to April 1-March 31, and an additional interim quota of 2,802 t was set for the period January 1-March 31, 2004. The 10,320 t TAC was maintained through to 2007/08. By 2009/10, the regulations were changed such that the vessels no longer had to fish a portion of their catch in southern SFA 4. The TAC was set at 11,320 t for the 2008/09 to 2010/11 management years and increased to 13,018 t in 2012/13. In 2013/14 and 2014/15 the TAC was set at 14,971 t. Commercial catch increased from approximately 10,000 t from 2005/06-2011/12 to about 15,000 t in the past two years (Figure 15) and the TAC has been taken in 2014/15.

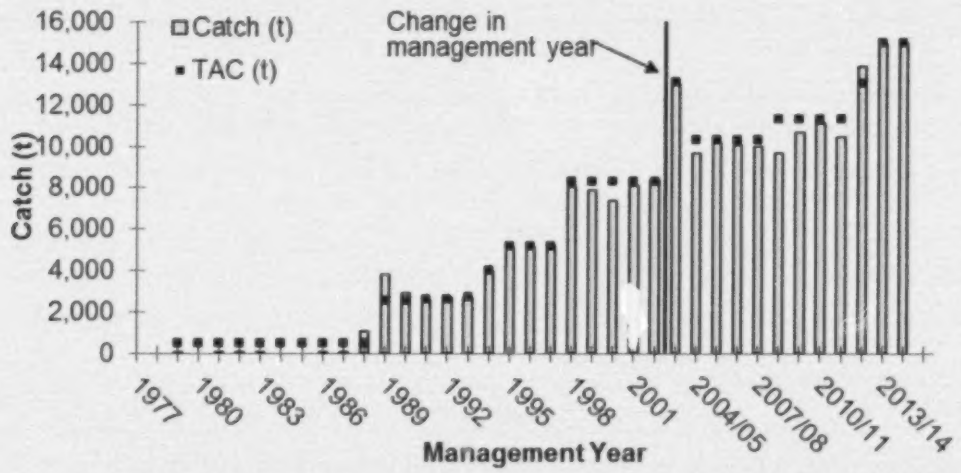

Figure 15. Historical Northern Shrimp catches and TAC, in SFA 4, for the period 1977-2014/15. In 2003, the management year changed from a calendar to a fiscal year.

Since 2010, large vessel standardized CPUE fluctuated above the long term mean (Figure 16). Several factors including changes in management measures and species composition of catches confound the interpretation of fishery performance in this area.

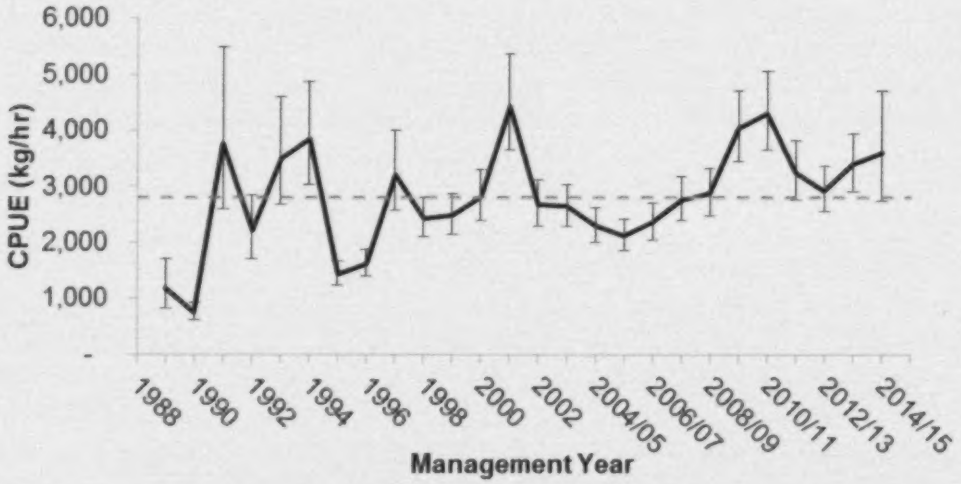

Figure 16. SFA 4 large vessel standardized CPUE for Northern Shrimp. Error bars indicate 95% confidence intervals and the dashed line indicates the long term average.

Biomass

Fishable biomass index has been relatively stable since 2010, and was 134,000 t in 2014. Female SSB index has changed little since 2010 and was 89,800 t in 2014 (Figure 17).

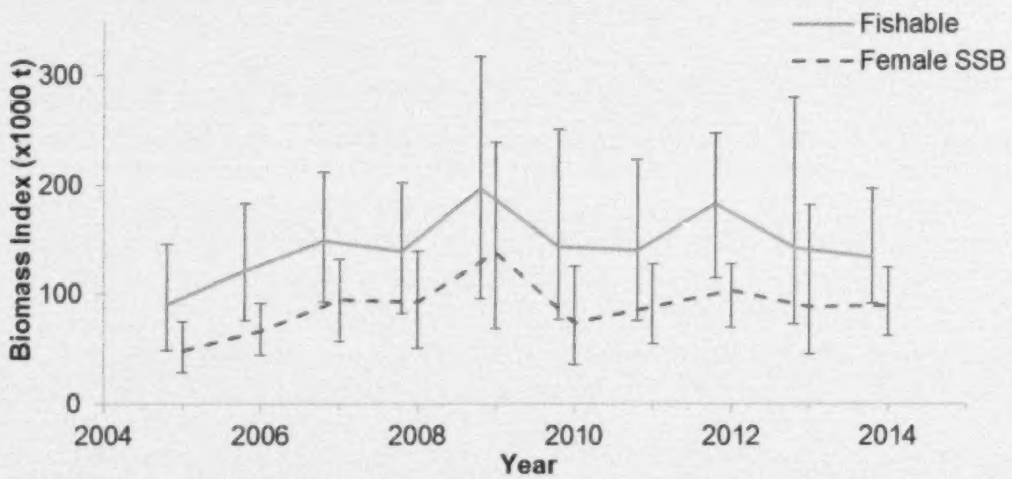

Figure 17. SFA 4 fishable (green solid line) and female spawning stock (purple dashed line) biomass indices for Northern Shrimp. Error bars indicate 95% confidence intervals.

Recruitment

Prospects for recruitment to the fishable biomass are uncertain.

Exploitation

Since 2010, the exploitation rate index has shown an increasing trend and reached 11.2% by 2014/15 (Figure 18).

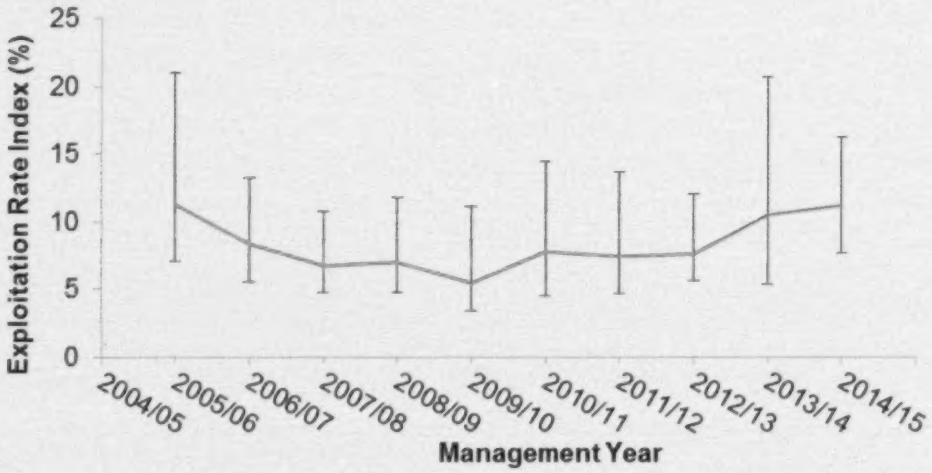

Figure 18. SFA 4 exploitation rate index for Northern Shrimp, based on total catch in current year/fishable biomass index from current year, expressed as a percentage. Error bars indicate 95% confidence intervals.

Current Outlook and Prospects

Female SSB index was assessed to be in the Healthy Zone, within the PA Framework (Figure 19).

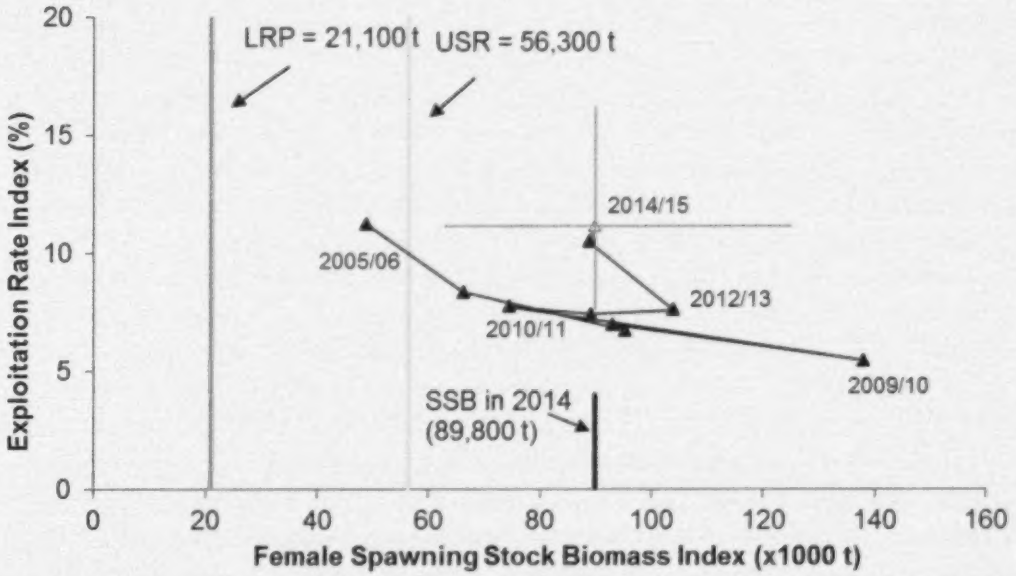

Figure 19. SFA 4 IFMP PA framework with trajectory of exploitation rate index versus female spawning stock biomass index for Northern Shrimp. Point labels denote year of the fishery. The red cross on the 2014/15 point indicates 95% confidence intervals for the 2014 female SSB index (horizontal) and the 2014/15 exploitation rate index (vertical).

SFA 4 *Pandalus montagui*

Fishery

Commercial catch of *P. montagui*, taken as by-catch in the *P. borealis* fishery, increased from 280 t in 2008 to 4,700 t in 2012 and declined to 1,200 t in 2014. The by-catch limit of 4,033 t has not been taken in the past two years (Figure 20). From 2002-12, the sole source of catch information for Striped Shrimp was logbooks, however by-catch was recorded in the CAQR beginning in 2013.

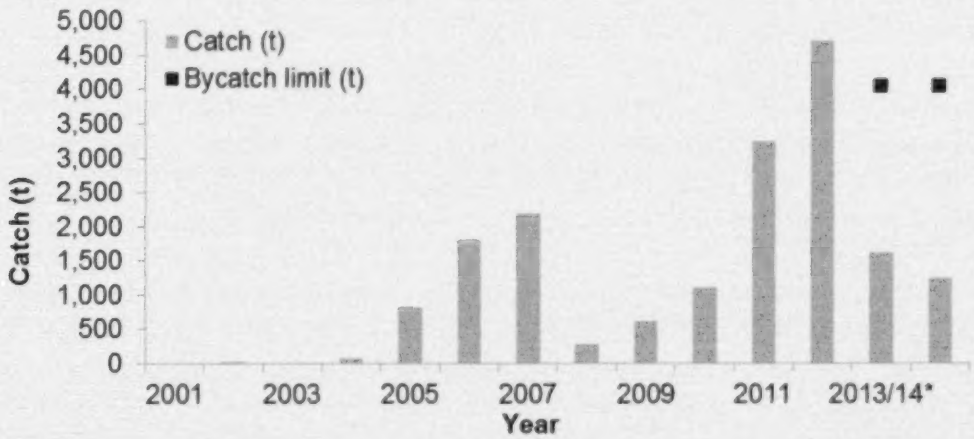

Figure 20. SFA 4 Striped Shrimp catch for the period 2002-2014/15, along with the by-catch limit established beginning in 2013/14. The catches from 2002-12 were based on log books within calendar year whereas the catch from 2013/14 onwards was based on the Canadian Atlantic Quota Report (CAQR – updated January 30, 2015) within management year.

Biomass

Fishable biomass index has fluctuated over the time series. It has doubled since 2010 and was 34,100 t in 2014 (Figure 21). The pattern is complementary to that observed in the Eastern Assessment Zone, to the north (DFO 2015). The fluctuations in biomass indices likely result from transfer across management boundaries rather than local dynamics within a population.

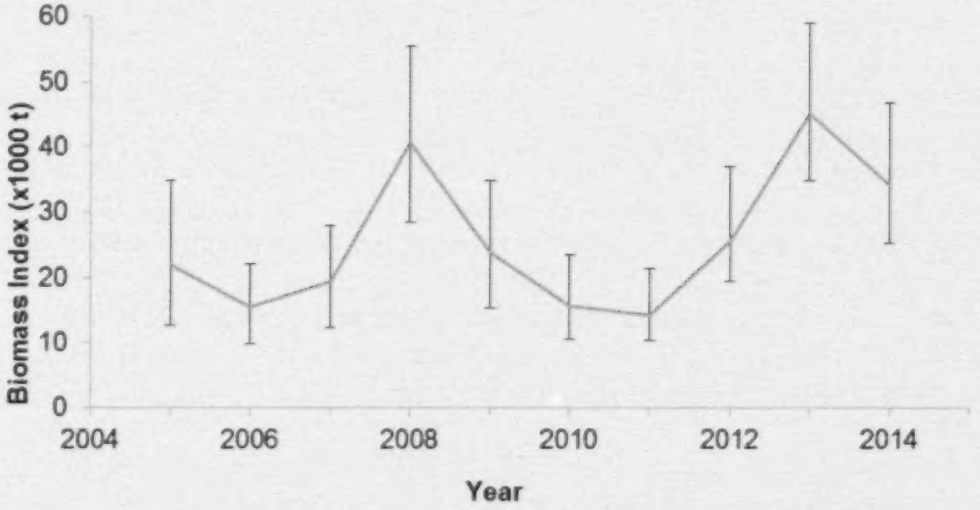

Figure 21. SFA 4 fishable biomass index for Striped Shrimp. Error bars represent 95% confidence intervals.

The female SSB that is relevant to a PA for an area consists of the animals whose spawning products will ultimately be caught in that area (as opposed to the animals that spawn in the area). The strong currents that likely advect all sizes of shrimp, especially larvae, into SFA 4 create especially severe problems with estimating female SSB for this particular SFA. The true female SSB is more than the females observed by the survey within SFA 4. Therefore, female SSB for Striped Shrimp is unknown in SFA 4.

Recruitment

Prospects for recruitment to the fishable biomass are unknown.

Exploitation

The reported exploitation rate index in 2014/15 was 3.6% (Figure 22). The exploitation rate index would have been 11.8% in 2014/15 if the by-catch limit had been taken.

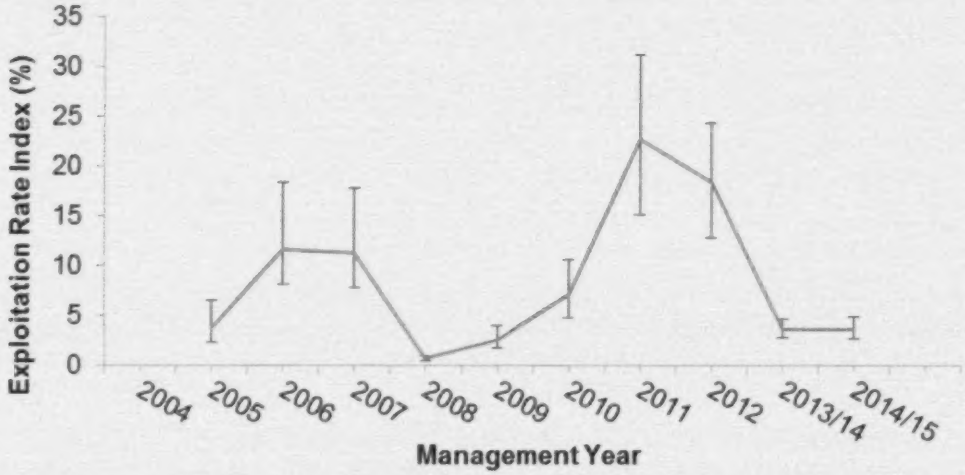

Figure 22. SFA 4 Striped Shrimp exploitation rate index, based on total catch in current year/fishable biomass index from current year, expressed as a percentage. Error bars indicate 95% confidence intervals.

Current Outlook and Prospects

The potential exploitation rate index of 11.8% is below the 20% maximum exploitation rate index that is proposed for a healthy SFA 4 resource. However, without a reliable female SSB index, the status of the resource relative to a PA framework could not be determined.

Sources of Uncertainty

SFAs 5 and 6

Estimates of predation on the shrimp population, in comparison with its productive potential, appear in assessments for the first time this year. They depend on a number of assumptions that may need to be investigated and refined:

1. It is assumed that there is always sufficient prey available to predators; however, this is not always true.
2. It is assumed that the diet composition (and species overlap) observed in stomachs collected in autumn surveys applies throughout the year.
3. Inferences for future consumption require further assumptions about how the diet composition changes as the relative amount of different prey types changes.
4. It may well be that many of the shrimp found in stomachs of predators are of a size too small to be caught well by the research survey gear.
5. The P/B ratio gives an upper bound on the amount of shrimp production. The higher predation pressure is, the more shrimp will be eaten early in the year, before their (potential) production can happen.

Furthermore, the ecosystem in which shrimp live is changing. Predator populations are increasing, and the physical determinants of production are expected to change in unknown ways. These changes raise questions about a PA framework which was designed around the assumption of stable ecosystem conditions.

SFAs 4-6

Spatio-temporal variation in survey efficiency among three DFO research vessels, particularly in NAFO Division 3K (SFA 6) is a source of uncertainty and the implications are unknown. Though the timing of the survey, and the proportion of sets performed by either research vessel, may change slightly from year to year, it is assumed that the effects are insignificant.

The survey in SFA 4 had been conducted by the *Cape Ballard* from 2005 to 2011. Beginning in 2012, the *Aqviq* was used. In 2014 the vessel was again changed and the *Kinguk* was used. Because vessel specifications were similar and there was no change in the survey gear or design, it was assumed that any effect of this change in the survey vessel would not be significant. However, no inter-calibration was conducted.

The female SSB that is relevant to the PA for an area consists of the animals whose spawning products will ultimately be caught in that area (as opposed to the animals that spawn *in* the area). The strong currents that likely advect all sizes of shrimp, especially larvae, into an area create especially severe problems with estimating female SSB, for SFA 4 in particular. Accordingly, the true female SSB is more than the females observed by the survey alone. The existing management areas may not represent biological units. Causes in one management area may produce effects in other management areas.

There is no risk analysis for this resource. There is uncertainty in the appropriateness of the provisional reference points as it is unknown how the survey biomass relates to the biomass of maximum sustainable yield (B_{MSY}).

For the exploitation rate calculation, both the numerator (catch) and denominator (fishable biomass) are uncertain. Trawls used in the surveys have shrimp catchability less than one but the true value is unknown. Therefore, the survey underestimates biomass by an unknown percentage which may vary annually. Although the commercial catch is believed to be known without error, the total fishery-induced mortality is unknown (landed catch plus incidental mortality from trawling). Therefore the exploitation rate index imprecisely estimates the exploitation rate by an unknown percentage.

Physical changes in the environment (e.g., temperature) may affect the distribution and hence the availability of shrimp to commercial and survey trawls.

Exploitation rate is far from spatially uniform in SFA 4 for *P. montagui*. A large fraction of the fishable biomass estimated from the survey is in a region that is never fished; therefore the local exploitation rate in the small area fished in the north is far greater than the nominal exploitation rate.

CONCLUSIONS AND ADVICE

SFA 6 *Pandalus borealis*

There is concern for the current status of this resource. The female SSB index is below the mid-point of the cautious zone, based on the PA framework, for the second consecutive year. If the TAC is taken, as it is expected to be, in 2014/15 the exploitation rate index will be 22.3%. If the 48,196 t TAC is maintained and taken in the 2015/16 season, the exploitation rate index will be 20.7%. Fishery removals may be becoming a large fraction of the net difference between shrimp production and total predation in recent years. Thus, fishing mortality can be very important for determining whether gains (production) exceed losses (predation) and hence whether the stock is increasing or decreasing.

SFA 5 *Pandalus borealis*

Current status of this resource is positive, at levels close to 2012. Female SSB index was assessed to be in the Healthy Zone within the PA framework. If the 20,970 t TAC is maintained and taken in 2015/16, then the exploitation rate index will be 18.1%.

SFA 4 *Pandalus borealis*

Current status of this resource is positive. Female SSB index was assessed to be in the Healthy Zone, within the PA Framework.

SFA 4 *Pandalus montagui*

The potential exploitation rate index of 11.8% is below the 20% maximum exploitation rate index that is proposed for a healthy SFA 4 resource. However, without a reliable female SSB index, the status of the Striped Shrimp resource relative to a PA Framework could not be determined.

MANAGEMENT CONSIDERATIONS

In general, management of key forage species such as shrimp, under an ecosystem approach, requires adoption of a conservative approach with lower fishing mortality reference points and higher biomass reference points than those that would be adopted under a single species management approach. Keeping the exploitation rate at or below 15% for the Healthy Zone of the PA framework is thought to be conservative and leaves forage for predators. A better understanding of ecosystem demands on shrimp as a forage species is required.

Effects of ecosystem changes and climate change on shrimp resources should be considered when making management decisions. For example, positive correlations have been found between the timing of the annual phytoplankton production cycle and a 3-4 year lag in fishable biomass and commercial fishing performance, indicating that these environmental variables have an impact upon the early life stages in some areas. However, there is a need to conduct more research to determine whether environmental variables could be used in conjunction with recruitment studies to produce resource status predictions.

As predator biomass increases and shrimp biomass decreases, fishery removals may be becoming a large fraction of the net difference between shrimp production and total predation in recent years. Thus, fishing mortality can be very important for determining whether gains (production) exceed losses (predation) and hence whether the stock is increasing or decreasing.

SOURCES OF INFORMATION

This Science Advisory Report is from the February 17-23, 2015 Assessment of Northern and Striped Shrimp. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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Aussi disponible en français :

MPO. 2015. Évaluation de la crevette nordique (Pandalus borealis) dans les zones de pêche de la crevette 4 à 6 (divisions de l'OPANO 2G-3K) et de la crevette ésope (Pandalus montagui) dans la zone de pêche de la crevette 4 (division 2G de l'OPANO). Secr. can. de consult. sci. du MPO, Avis sci. 2015/018.